No. 299 BULLETIN OF THE AGRICULTURAL EXTENSION SERVICE, THE OHIO STATE UNIVERSITY JUNE, 1948

SURFACE DRAINAGE Of Flat Land

Promotes Prosperous Farming

By

ROSS MILNER
County Agricultural Agent, Ashtabula County

THE OHIO STATE UNIVERSITY AND THE U. S. DEPARTMENT OF AGRICULTURE, COOPERATING
AGRICULTURAL EXTENSION SERVICE, H. C. RAMSOWER, *Director,* Columbus, Ohio
Printed and distributed in furtherance of Acts of May 8 and June 30, 1914

Surface Drainage of Flat Land

By Ross Milner

The author is grateful to John A. Slipher, Ohio Extension Service Soil Conservationist; Virgil Overholt, Ohio Extension Service Agricultural Engineer; Earl Jones, Ohio Extension Service Agronomist; and Don Hover, District Conservationist, Soil Conservation Service. Each of them read the manuscript and offered many helpful suggestions before it was printed.

PART I. PLACE AND PURPOSE OF SURFACE DRAINAGE

Surface Drainage Defined.—Surface drainage removes surplus water from the surface of crop fields, pasture land, and fruit plantings. It is adapted to farms where the land is flat and the subsoil is heavy and compact. Under these conditions it is useful on both tiled and untiled fields. In function, it differs from tile drainage in which the excess water moves into the soil, then through it where it finally escapes in tile lines. The purpose of surface drainage is to rid land quickly of its excess water and thereby prevent the land from becoming soggy. Surface drainage may be used alone or as a supplement to tile drainage.

Soils where surface drainage is useful are similar to Mahoning silty clay loam or silt loam. The soil particles of such soils are so small they settle very slowly when suspended in water. The subsoil tends to become water-tight due to the fine particles being washed from the plow layer downward into the subsoil. There they lodge in the pores and cause them to become plugged. This reduces the movement of water into and within the soil.

Surface drainage of flat, heavy, compact soils benefits farming because it:

1. Permits more timely planting, cultivating, harvesting, and manure hauling.
2. Results in warmer ground temperatures during the spring season (wet soil is colder).
3. Promotes multiplying of beneficial soil bacteria.
4. Improves the tilth or looseness of the soil.
5. Results in larger crop yields and more luxurious pasture.
6. Stimulates deeper rooting and better stands of legumes.
7. Increases organic matter and soil productivity as a result of the above benefits.

Basically, surface drainage consists of two parts:

1. Removing water directly from fields which need draining—by drainage channels.
2. Preventing water from flowing onto fields where excesses normally accumulate—by diversion terraces.

Wet Fields are a Handicap.—Sometime during almost every year, one's farming operations are slowed down or stopped, due to excess water. In some years, the excess occurs at plowing and planting time; in others, at cultivating or at harvesting time. Also, wet fields occasionally prevent daily spreading of manure. Wet fields thereby delay farming operations and result in one's getting behind with his work. Additional losses thus occur because of late planting and delayed harvesting.

There are still other losses. Wet soil is actually colder. It requires several times as much heat to warm soil water as to warm a like quantity of earth particles. Still less heat is required to warm the air that replaces the excess water drained from the soil. Cold soil retards the growth of crops in the spring.

Large numbers of beneficial soil bacteria are necessary to prepare plant food. They are at a minimum in wet soil because they require air and warmth for rapid multiplication.

When heavy soil is wet for a long period, it becomes compact, lacks good "tilth," and the crop roots extend into it slowly.

Alfalfa, clover, wheat, and other crops that live over winter "heave out" to a greater extent on wet soils. Excess water at the very surface causes the greatest heaving losses. Sometimes a stand is lost entirely because of excess water.

All these delays and losses add up to a big figure.

Furthermore, the soil productivity can be built up faster on drained land, because of greater multiplication and activity of beneficial soil bacteria, deeper rooting of crops, and the opportunity of growing more water-sensitive crops like alfalfa in mixtures.

Conditions Where Surface Drainage Is Desirable.—Soils suited to surface drainage can be recognized in several ways:

1. Water stands in tracks and low places for more than a few hours after a heavy rain.
2. The color of the subsoil is marked by gray or blue in a mixture with brown or yellow, beginning 8 to 14 inches below the surface.
3. By the existence of a hardpan or tight layer in the upper subsoil.
4. The subsoil within a depth of 30 inches is surprisingly "dry" even after an extended rainy period.
5. The type of plants in old dead furrows and other slight depressions and in permanent pastures has gradually changed to rushes, reeds, and other plants which tolerate excess moisture.

Why Well Planned Surface Drains Are Useful.—Large quantities of water fall on the land. During periods of heavy rainfall, the soil receives more water than it can usefully absorb. A 1-inch rain deposits 27,154 gallons of water on each acre of land. Annual rainfall varies from year to year. Likewise, the distribution of rainfall varies from month to month within a year. The rainfall at Jefferson, Ohio, has been measured by the Postmaster for several years. His records show the average rainfall during the 14 years, 1933 to 1946, was the heaviest in April, May, June, July, August, September, and October. These are the months when the soil is plowed, fitted, and planted and when crops are cultivated and harvested.

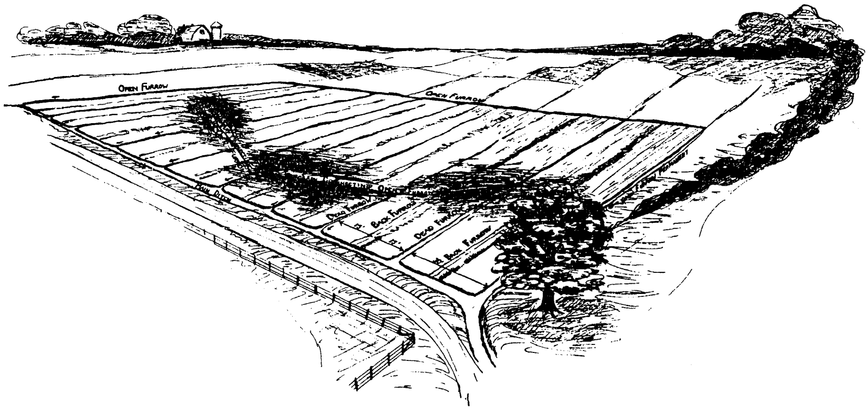

Fig. 1—Illustration of land in need of surface drainage. The soil is flat, heavy, and compact.

Table 1.—Sample Monthly and Annual Rainfall in Inches at Jefferson, Ohio

Month	*1934*	*1936*	*1942*	*1945*	*Ave. 1933–1946*
January	1.23	1.16	8.57	1.72	2.86
February	1.18	1.87	3.58	4.42	2.64
March	2.56	5.08	1.73	3.65	2.90
April	2.77	1.85	3.06	3.20	3.23
May	.52	2.22	6.30	4.70	3.94
June	1.05	2.28	8.57	4.87	3.77
July	2.18	3.35	7.80	1.30	3.62
August	7.32	2.69	4.15	2.80	3.38
September	6.27	1.24	2.52	8.57	3.28
October	1.90	3.14	5.44	6.30	3.46
November	3.44	3.63	3.90	3.18	2.84
December	1.22	1.61	3.55	1.87	2.55
Total	31.64	30.12	59.17	46.58	38.47

Excess rainy periods may occur any time during the year. These may come during the winter, when daily manure hauling has to be interrupted, or at planting, cultivating, or harvesting time. The wet period in 1934 was August and September; 1936, March; 1942, January, May, June, and July; and 1945, September.

When an excess of rainfall occurs, part of the water starts moving over the surface until it settles in low areas, dips, or swamps. This means that such places receive not only the rain water that falls on them, but the additional water from higher areas. Thus a field, which has not been surface-drained, may have several spots where the excess water runs off rapidly;

others where the excesses accumulate. Where low areas have several acres in the "watershed" above them, they receive burdensome quantities of water. In fact, water may continue to flow onto them for several days while the surplus is draining from the higher areas.

FACTORS TO CONSIDER IN PLANNING SURFACE DRAINAGE.—The goal of surface drainage is to handle an entire field so that all the excess water will continually move into an outlet, which in turn will pass it on as rapidly as received.

Water always flows to lower levels unless impounded by a ridge, headland, or other barrier. This principle of motion should be kept in mind. Thus, standing water is impounded water. It is a challenge to man's skill to plan a system that will keep the excess flowing from all parts of the fields at a slow but continuous speed.

Since rapid runoff results in erosion, care must be used in developing a safe as well as sufficient grade.

A skillful plan of ditching requires a knowledge of several factors. These include.

1. The watershed, that is, the acres of land drained from above. Frequently, part of a neighbor's land may drain onto the field.
2. The nature of the subsoil in the field and throughout its watershed.
3. The topography of the field, including the slope, length of slope, variations in elevation, wet spots, and ridges.
4. The outlet channel including its grade, capacity, and its elevation in relation to the field to be drained.
5. Locations where ditches will cause the least inconvenience in cropping or pasturing operations. Frequently, the ditches can be located beside fences or between fields. Relatively long, narrow fields are much more efficient to operate.

Usually, the most skillful plan consists of an intelligent compromise of these factors, resulting in effective drainage with a minimum of inconvenience in farming the field.

The remainder of this bulletin describes the construction and maintenance of surface drainage channels and terraces.

PART II. CONSTRUCTING BEDS

Before a surface drainage system is started, one should think of his entire farm and the water that may flow onto it from neighbors' farms and from road ditches. Part I of this bulletin describes the conditions where surface drainage is desirable, why wet fields are a handicap, why well planned surface drains are useful, and a list of the factors to consider in planning surface drainage. It should be recalled that surface drainage is recommended only on fields having flat surfaces and heavy, compact subsoils.

It is essential that an adequate outlet is available or can be constructed. The location and elevation of the outlet must be kept in mind, so that the entire surface drainage system will work as a related unit.

In discussing the construction details, we shall first explain the construction of devices in the field where the surplus water originates. We shall follow with other devices, step by step, in the course taken by the water until it reaches a permanent outlet.

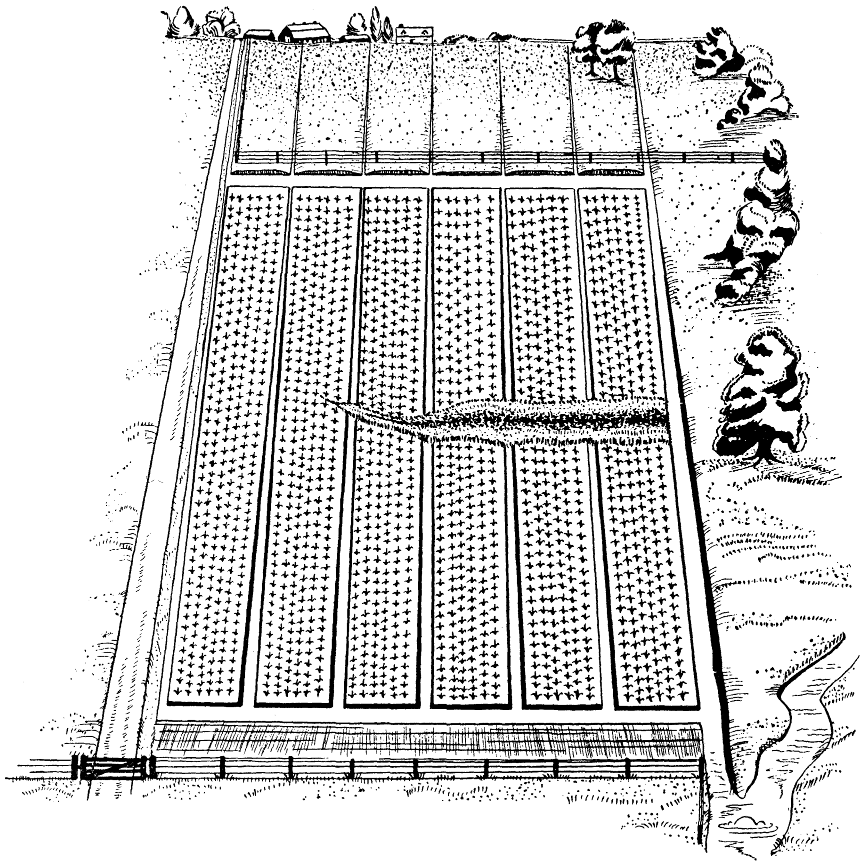

Fig. 2—Illustration of a complete drainage system. Corn and pasture are thriving on the beds. Water on these beds moves to the dead furrows, to the collection ditch, grassed waterway or collection terrace, to the outlet ditch, and finally to the stream.

A "bed" is the soil between two dead furrows. It is often called a "land." The goal in constructing a bed is to grade the soil so that all parts of its surface slope continuously toward a dead furrow. The dead furrows serve as channels and function as "veins." They collect the excess water from the sloping sides of the beds and carry it to large channels. To function satisfactorily, these dead furrows must have a continuous grade without any impediments to impound the water.

Figure 3 illustrates the common method of plowing when a field is plowed into beds. All the furrows are turned toward the back furrow which, of course, is midway between the dead furrows and is made by throwing the first two furrows together.

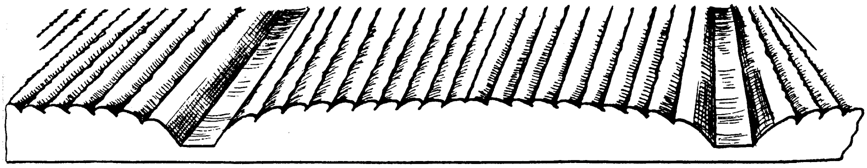

Fig. 3—The usual method of plowing with a back furrow in the center of the bed.

This method has both strong and weak points, depending on the drainage conditions. It is desirable where a new bedding system is being established or where an old one is being relocated. But, it is an undesirable method of plowing provided the beds have already been established and are to be continued in the same location. It results in the crowns of the beds getting higher; the dead furrows lower.

It is desirable to relocate the beds each time the field is plowed, if the temporary beds are sufficient to provide adequate drainage. Usually, they are not so skillfully constructed because the operator does not feel justified in taking much time on temporary beds that are to be relocated the next time the field is plowed.

Slow-draining fields require a carefully established bedding system. Fortunately, there is a satisfactory method of plowing permanently established beds. The crowns do not get higher nor the dead furrows lower, regardless of the number of times the field may be plowed by this method. It is illustrated in Figure 4.

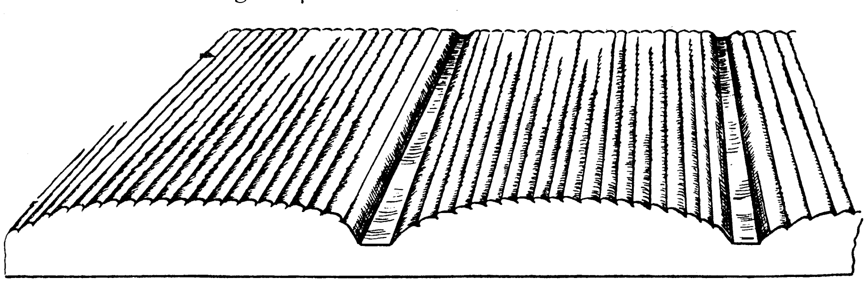

Fig. 4—A method of plowing permanently established beds which keeps the crowns and the deal furrows at a constant elevation.

This method of plowing is useful on fields that are unusually flat and slow to drain. The field should first be carefully and skillfully bedded by developing the proper width, height, and side-slope of beds and a sufficient grade in the dead furrows. This may likely require more than one year.

Two beds are always plowed as one land. The first furrow on each new land is turned toward a dead furrow. On the return trip a corresponding furrow on the opposite side of the dead furrow is also turned in. These two furrows of the first round are located far enough apart so that about 12 inches of the old channel remains between them. All the remaining furrows in these two beds are then turned toward these two furrows as illustrated in Figure 4. When the two beds have been plowed, one moves to the third dead furrow where he starts plowing the next "pair of beds" just as the first pair was plowed.

It will be observed that the dead furrows between each two beds which were plowed as a pair still remain. These are about normal width. The newly plowed dead furrows on either side, however, are about twice the normal width. Thus normal and twice-normal width dead furrows alternate. For this reason, each time the field is replowed, one should start plowing at the twice-normal dead furrows, thereby changing them to normal width and vice versa.

DETERMINING PROPER WIDTH OF BEDS.—The selection of the proper width of beds is important in achieving good surface drainage. There are four factors to consider in determining the best width of beds:

1. *The slope of the field.*—The flattest fields require more narrow beds.
2. *The tightness of the soil.*—The slowest draining soils also require narrow beds.
3. *The number of rows of corn that can be planted on a bed.*—It is usually unprofitable to grow corn in the dead furrows. A row in the dead furrow requires as much seed, fertilizer, cultivation, and harvesting time as each of the other rows; but it seldom produces enough to justify the production costs. If the dead furrows are not to be planted to corn, this should be taken into consideration when deciding the width to make the beds.

The following table shows the necessary width of beds for 6 to 14 rows of corn after allowing 2 extra feet of space at the dead furrows.

Table 2.—Widths of Beds to Allow from 6 to 14 Rows of Corn

No. of Corn Rows	*Row Spacing*	*Allowance for extra space at dead furrows*	*Width of Bed*
6	3½ ft.	2 ft.	23 ft.
8	3½ ft.	2 ft.	30 ft.
10	3½ ft.	2 ft.	37 ft.
12	3½ ft.	2 ft.	44 ft.
14	3½ ft.	2 ft.	51 ft.

Figure 5 illustrates a bed 30 feet wide which has been crowned for good surface drainage. It shows that eight 3½-foot rows of corn have been planted and a 2-foot wider spacing of rows at the dead furrows has been allowed.

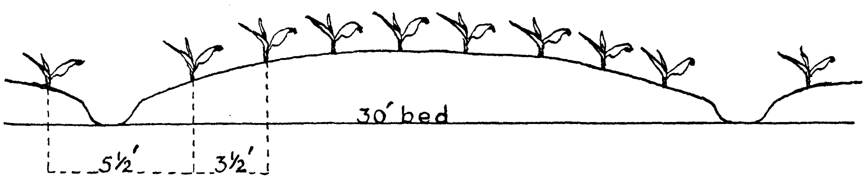

Fig. 5—Example of a bed in which the proper width has been carefully planned, including the spacing of corn rows.

4. *The plow.*—Plowing time will be saved if the width of the beds is a multiple of the width of one round with the plow. For example, one round with a standard two-bottom 14-inch plow, if properly set and operated, will plow a width of 56 inches.

Table 3.—Width of Beds Made by Rounds of 2–14" Plow

No. of rounds with 2–14" plow	*Width Plowed Feet*
5	23⅓
6	28
7	32⅔
8	37⅓
9	42
10	46⅔
11	51⅓

The proper width of beds, therefore, depends upon slope of the field, tightness of the soil, proper allowance for corn rows, and for rounds with the plow.

When these factors are all considered in determining the width of beds, it results in good surface drainage and more efficient farming operations.

Let us assume one wishes to plant corn in rows 3½ feet apart on the beds and 5½ feet apart at the dead furrows; that the plow is a two-bottom, 14-inch size. The following table suggests desirable widths of beds, based upon the rate at which the field drains.

Table 4.—Width of Beds Based on Rate of Drainage

Rate Field Drains	*Corn Rows*	*Rounds with Plow*	*Width of Bed in Feet*
Very slow	6	5	23
Very slow	8	6½	30
Slow	10	8	37
Slow	12	9½	44
Fair	14	11	51

By consulting the above table, one can determine the proper width of beds for good surface drainage and for practical, efficient operation. Naturally, the beds should be as wide as good drainage will permit.

Usually, it will be desirable to select a width varying from about 23 feet on the slowest draining to about 51 feet on the quicker draining soils. The exact width, as explained, should be slightly increased or decreased properly to allow for corn rows and the width of plow.

DETERMINING PROPER HEIGHT OF BEDS.—Beds should be crowned as little as possible, and dead furrows should be as shallow as possible, consistent with good drainage.

A continuous side slope from the center of the bed to the dead furrow is essential, regardless of the height of the bed. Consistent side slope will permit less crowning of the beds.

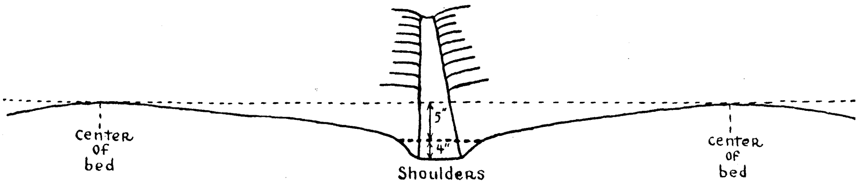

Fig. 6—A cross-section drawing of a bed showing continuous side slope and proper depth of dead furrow.

The total side slope from the center of the bed to the bottom of the dead furrow should not be less than 6 inches or more than 12 inches. Nine inches is desirable for most conditions. This total side slope of 9 inches should consist of 5 inches of fall from the center of the bed to the shoulder of the dead furrow, and 4 inches from the shoulder to the bottom of the dead furrow as illustrated in Figure 6.

Obviously, it requires skill to plow and fit the beds to build a continuous side slope of the proper fall. Improvement may be made at each successive plowing until the desired pattern is formed. Study and observation will reveal the shortcomings and point out the remedy to apply.

On the slowest draining soils, like those found on Trumbull silty clay loam, one is justified in taking more time to carefully lay out the beds. Once they are properly constructed, they should be considered permanent, and should not be relocated in future plowing. Established beds can be replowed without changing their side slope or the depth of the dead furrow. This method is described on page 7.

SOLVING CONSTRUCTION PROBLEMS AT END OF FIELD WHEN HEADLAND (turning strip) IS TOO HIGH.—Surface drainage systems now in use on many fields are of little value because the headland at the end of the field is too high. It traps the water in the dead furrows near the end of the field. Frequently, the water extends up the dead furrows for several rods and across the ends of the beds. This condition seriously delays farming operations, because the wet area extends across much or all of the end of the field, and is located adjacent to the turning strip, where the greatest traction is required.

During the past 75 to 150 years, previous plowing, discing, and even cultivating have, little by little, "terraced-up" the headlands, so that there is a definite reason for the headlands to tend to be high on all fields.

Fig. 7—Example of a headland which slopes in the wrong direction. The operator is pointing to the wet area at the ends of the dead furrows.

The headland usually extends into the field about 1 rod. Frequently it slopes 2 to 6 inches *in the wrong direction*. The wet area shown in Figure 7 resulted from a reverse slope of only 1 to 2 inches, yet it has prevented plowing and planting when the rest of the field was dry enough. On some farms, the correction of this problem alone will make the present surface drainage system function satisfactorily. There are two accepted plans for correcting it.

One plan consists of constructing a broad, shallow collection ditch like the one pictured in Figure 8. For this purpose it is located just inside the headland (turning strip) and collects the water discharged from the dead furrows. In this picture the headland is very wide. Generally it need be only wide enough to permit easy turning.

This plan leaves a slightly sloping, but smooth headland on which to turn. There are no dead furrows to cause a rough turning strip. On the other hand, the collection ditch creates a low area, which must be crossed, and must be maintained at the proper slope, kept free of soil, which would impound water, and preferably kept in sod to prevent erosion. The troubles usually encountered on headlands can be minimized if the turning strip and collection ditch are heavily limed, fertilized, manured, and planted to a permanent legume-grass sod, which can be harvested for hay. One should remember that in a typical rotation of corn, small grain, and 2 years of hay, these grassed areas will actually be in hay along with the rest of the field one-half the time. Thus the sod waterways and headlands will simply be

Fig. 8—A broad, shallow collection ditch. It collects the water from the ends of the dead furrows and discharges it into an outlet ditch.

Fig. 9—A headland which the owner has lowered. The slope now conforms with that of the rest of the field and permits shallow dead furrows to extend to the outlet ditch.

harvested for hay along with the rest of the field, except when the field is in corn and small grain.

The other plan for correcting the problem of high headlands consists of lowering the headland itself as pictured in Figure 9.

This means moving enough soil from the headland to change its slope, and thus permit the water to be carried in the dead furrows clear across the headland and discharge into a collection ditch at the extreme end of the field. This may be the road ditch, a stream, or a ditch between fields.

Generally much of the soil need only be moved into the field a short distance. Frequently, it is just a matter of moving it back to where it was before farm implements terraced it up in the course of farming.

The best choice of implements to move this soil depends on the amount to be moved and the distance it must be moved. Plowing and replowing (in one direction only) is a practical method where the soil does not need to be moved more than a rod or so. By turning all furrows toward the field, the entire headland will be moved the width of one furrow. On each repeat plowing one can move the headland a similar distance. Thus, with the original plowing and 13 replowings, using a 14-inch bottom plow, the entire headland would theoretically be moved 1 rod. A whirlwind type terracer plow may accomplish a similar result in somewhat less time.

Where it is necessary to move the soil a greater distance, a roll-over scraper or other soil carrying implement will be needed. Generally, farmers in northeastern Ohio, who have reversed the grade of their headlands, report that it takes time, but is well worth the effort.

After the headland has been lowered, shallow dead furrows, which can be crossed in turning, are extended across the headland.

On some fields the problem of high headlands can be solved best by constructing a collection ditch; on some, by actually lowering the headland; on others, either solution is satisfactory. Where the headland is too high, the importance of lowering it can not be over-emphasized.

Useful Equipment in Constructing Beds.—The farm plow, disc, and drag are usually sufficient implements on fields which have a continuous slope and no low spots or previous dead-furrow depressions.

However, when depressions exist, a blade scraper, roll-over scraper, or land leveler are useful. These tools can be purchased for little more than the cost of a disc, and where needed, soon pay for themselves. Their principal use lies in constructing beds so that they have a continuous side slope from the center to the dead furrow.

These implements can be drawn with farm tractors. They are standard equipment on many farms in some parts of the United States and should be more widely used in this area.

How to Build Beds When the Direction of Slope in the Field Varies. In many instances, the slope reverses itself within the field. When this is the case, the water from both directions moves down the dead furrow toward the low area, forming a pond or wet spot. This condition, and one solution, is illustrated in Figure 1.

Provided only one or a few dead furrows have a low area within the field, it is sometimes possible to channel the water in them across the adjacent beds to a near-by dead furrow which does have an unbroken slope.

It may be possible to lay a tile drain into the low area and construct a "French drain" of coarse gravel or small rocks over the tile to permit a rapid movement of surface water into the tile. A larger tile is required where surface water drainage is involved. Generally, tile drainage is designed to remove internal soil moisture, not surface water.

On the other hand, if the low area within the field extends across most or all the beds, a "collection ditch" within the field, running more or less at right angles or even obliquely to the dead furrows is needed. The construction of collection ditches is described in Part III.

Fig. 10—A shallow, temporary ditch which extends obliquely across several dead furrows that discharge into it.

PART III. CONSTRUCTING COLLECTION DITCHES

A collection ditch is a channel which draws water from both sides; usually from the dead furrows whose channels extend into it. There are two locations in fields where collection ditches are useful:

1. Where a low area exists which prevents the dead furrows from carrying water the entire length of the field.
2. At the headland (turning strip), provided it is too high for the dead furrows to be extended across it.

Both of these situations are described in Part II.

A collection ditch should be at least 4 to 6 inches lower than the dead furrows. In many situations, the channel must be still lower in parts of its course to obtain sufficient grade. The channel should be broad and shallow with flattened sides as pictured in Figure 11.

Where needed, a collection ditch is a valuable device: It removes water that would otherwise drain slowly or not at all. It permits the farming of large units of land as one field.

Steep-sided ditches are a common but less satisfactory alternative because they can not be crossed, thus creating two or more fields. Actually, in many instances, a unit of land has been split into three fields with the furrows in the low middle field running at right angles to the furrows in the two adjacent fields. This has resulted in improved drainage by taking advantage of natural slopes, but it has been at the cost of having to farm small fields. These small fields result in more turning of implements, more hours in plowing, cultivating and harvesting, more fencing material, and more fence corners.

Collection ditches should usually be grassed to prevent erosion. Implements should be lifted or straightened when crossing a grassed waterway. This is somewhat inconvenient, but results in better drainage and in greater farming efficiency, with little or no erosion. The more common use of tractors and tractor equipment has increased the importance of developing large, long fields. Thus, where practicable, the small fields established during horse-farming times should be combined to obtain efficient tractor operation. Frequently, collection ditches constructed with broad, shallow channels are the only means by which a large unit of land can be drained as a single field.

The collection ditch shown in Figure 11 was constructed with a typical farm plow drawn by a two-plow tractor. This ditch will be limed, heavily fertilized, heavily manured, and seeded to a permanent hay mixture. To protect the permanent sod, the plow, cultivator, and similar tools must be lifted when crossing the ditch. An example of the function of a collection ditch within a field is illustrated on the cover of this bulletin. The dead furrows in the low area of the corn field are discharging into the grassed collection ditch.

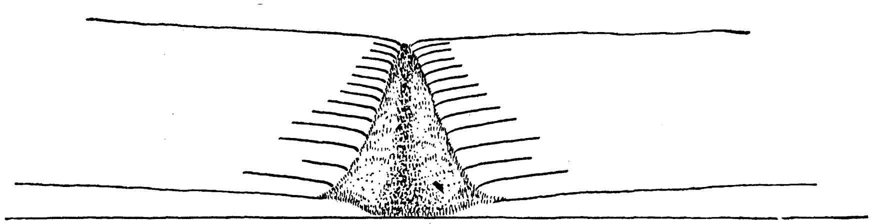

Fig. 11—Illustration of a good collection ditch within a field.

The collection ditch shown in Figure 11 was constructed by following the progressive steps illustrated in Figure 12. The goal is to make a broad, shallow channel with the soil distributed over a wide zone to permit easy crossing with implements.

The course for the ditch should be carefully laid out to follow the lowest levels. It must be at the lowest level if the dead furrows from both sides are to discharge into it. Generally, the use of an engineering level is advisable in locating the course for the ditch. The level will also be useful in constructing the ditch to grade. There should be no less than a $\frac{2}{10}$ percent grade ($2\frac{4}{10}$ inches per 100 feet), and for easy maintenance, no less than a $\frac{3}{10}$ percent grade.

When the course has been determined, the first steps in constructing the ditch are to mow and remove all vegetative growth and to disc and redisc the entire area to be plowed. This will make the plowing and repeated plowing much easier.

The farm plow is usually the most practical implement to use in moving the soil. The first furrow is plowed parallel to the eventual ditch, but 16 feet to one side. On the return trip, the second furrow is turned 16 feet on the opposite side. In other words, the furrows of the first round are 32 feet apart. All furrows are turned outward during the entire construction. The plowing continues and a dead furrow results where the center of the eventual ditch will be.

Provided the plowed area was in sod, it should be thoroughly disced even though it was disced before plowing was started. This will make repeated plowing much easier. Following the discing, replowing the area is next commenced. Each repeated plowing begins by throwing the outside furrow one furrow-width farther from the ditch, as illustrated in Figure 12. The plowing then continues in the standard manner until the plowed area is all replowed. Eight to twelve repeated plowings will be necessary to obtain a ditch 10 to 14 inches deep. During these repeated plowings, the spoil bank is moved farther from the ditch, and the ditch is broadened and deepened. Attention is again called to Figure 12 where the progressive steps of construction are illustrated. It will be observed that the ditch is deepened only during every other replowing. The collection ditch, when completed, will discharge its water into an outlet ditch.

Most collection ditches should be seeded and grassed over to prevent erosion. A discussion of grassed waterways will be found in Part VI.

PART IV. CONSTRUCTING OUTLET DITCHES

An outlet ditch is a channel which receives the water discharged from collection ditches, diversion terraces, and grassed waterways. It is also called a carrying ditch.

There are five main requirements for an outlet ditch:

1. A channel deep enough to receive the water discharged from the collection ditches without slowing its velocity.
2. Sufficient capacity to carry the water without overflowing.
3. Enough grade to permit a free and continuous flow without serious

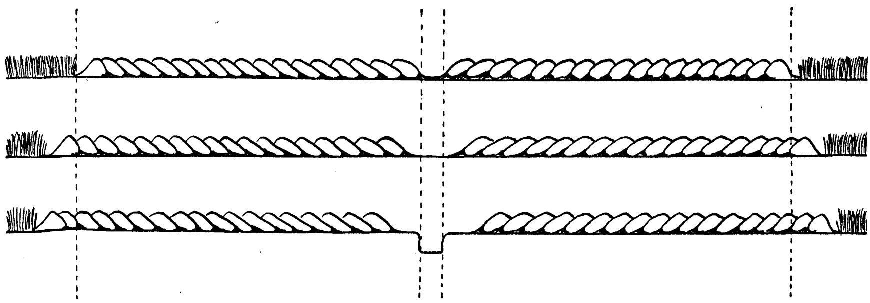

Fig. 12—Progressive steps in constructing a collection ditch with a plow.

silting. The grade should be at least ¼ percent (3 inches in 100 feet).

4. Bank slope flat enough to prevent sloughing of the sides. Even ditches that will not be mowed should not have a steeper slope than 2:1 (2 feet horizontally for each foot of depth). Ditches that will be mowed must have a bank slope no steeper than 3:1.
5. As little hazard to livestock as possible. Ditches with steep sides are a potential hazard to cattle and horses. Once an animal gets down in a ditch, it may not be able to get out.

Outlet ditches can be constructed or deepened by using one of several types of equipment:

1. The plow, by plowing and repeated plowing. Ditches 30 inches deep have been made in this manner although 14- to 18-inch depths are usually considered the practical limit. The procedure is described in Part III under the explanation of constructing collection ditches.

   An equally satisfactory outlet ditch may be constructed with a plow. There are many situations, however, which do not permit plowing back the spoil banks in the construction of outlet ditches.
2. A whirlwind terracer plow consists of a standard type plow and the addition of a revolving vertical screw which shatters the furrow and throws it several feet to the side of the plow. This screw has been designed so that all the soil is thrown to the right of the moldboard. The results are similar to those obtained with a breaking plow, but are accomplished in somewhat less time, due to fewer required repetitions in plowing. The ditch can also be made closer to a fence or trees.
3. Blade scrapers. The depth varies with the length of blade and size of grader. Scrapers pulled by a two-plow tractor will cut ditches 24 to 36 inches or slightly deeper under favorable conditions.
4. A scoop scraper for shallow ditches.
5. A power shovel, dragline, bulldozer, or other larger dirt moving equipment which is usually hired. Frequently, farmers find the

cost of hiring a large ditch constructed is considerably less than they supposed. Estimates should be obtained before custom work is undertaken.

6. Blasting with ditching dynamite. This may be the most satisfactory method where the soil is swampy and wooded. The limit of depth varies from about 28 inches in heavy compact clay soils to 60 inches in light muck-like soils. However, in these heavy soils, greater depth can be obtained by using more dynamite in the holes or by repeated blasting. The resulting bank slope is about 2½:1, although it varies with soil and moisture conditions.

Opening Ditches with Dynamite.—Where it is desirable to clean or lower an outlet ditch, blasting is sometimes practical. Dynamite performs well in wet, swampy, wooded places which would be difficult to dig by hand or machine. Because of the cost of moving heavy ditching equipment, it may prove to be the quickest and cheapest method of opening short ditches even though conditions would permit the using of a machine. Dynamited ditches, however, do not make a satisfactory bed for tile because the bottom is left shattered and loose.

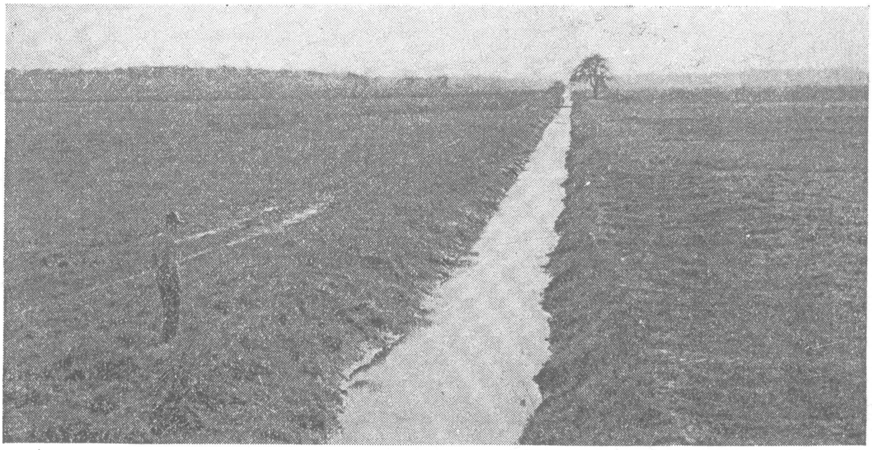

Fig. 13—A satisfactory outlet ditch. It has sufficient capacity to carry the water it receives.

The "propagation" method of firing is recommended. This method was used in opening the ditch shown in Figure 14. It consists of applying a single cap to only one stick in the entire row of sticks. All the remaining sticks are exploded by the wave action of the blast which is carried by the water in the soil. Since a cap costs about as much as a stick of dynamite, the saving by "propagation" is apparent. The soil must be wet; therefore, spring is usually a better time than fall for dynamiting. As a general rule, if water comes out between the fingers when a handful of soil is squeezed, the dynamite will "propagate." Light muck-like soils blast better than heavy clay, sand, or gravel. Dynamite can be used in heavy clay soils, but the ditch can not be made as deep if the clay is very heavy and compact, due to its greater resistance to being moved. Under these conditions extra skill in placing the stick is required. A repeat blasting, or the placing of more sticks in the holes may also be necessary to obtain the desired depth.

Using "Ditching Dynamite." It is a high grade of 50 to 60 percent straight nitroglycerin, and has a heavy coat of paraffin. The sticks are of uniform weight and especially prepared for "propagation" ditching. Dynamite is sold in 50-pound boxes of 100 sticks; each stick weighing ½ pound. Half sticks can sometimes be wisely used. Generally no seal is necessary where the sticks are divided. To divide a stick, punch a hole across the center with a sharpened piece of wood; then break the stick in two.

Since the close of World War II, no license is required.

Begin loading the dynamite (placing the sticks) at the lower end and work up. This reduces the amount of silt deposited in the ditch if rains occur before construction is completed. A string should be stretched to permit placing the charges (sticks) in a straight line. Eighteen inches is a common spacing between charges. At this spacing, the ditch will average about 8 feet wide at the top. Vary the spacing slightly as conditions warrant.

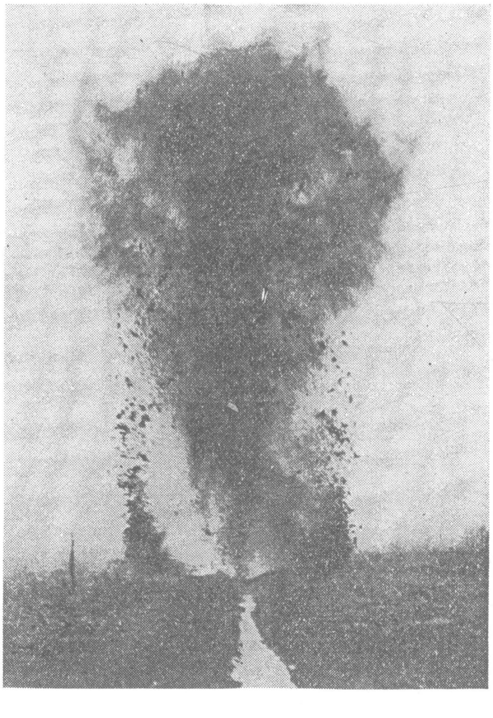

Fig. 14—A ditch being opened with dynamite.

However, it is false economy if spacings are so far apart that misfires result or the ditch is too shallow. A trial shot of six to eight charges (sticks) is recommended because the size and shape of the blasted ditch can not be accurately predicted. Results are greatly influenced by soil texture and moisture content.

Beginners commonly place the sticks too deep. Usually a 2-foot depth (to the bottom of the stick) will make a ditch 3 to 3½ feet deep. Open the hole with a crowbar or auger, preferably 1½ inches in diameter. Push the sticks into place in the hole with a wood stick; a broomstick with the big end sawed square is suitable. Load and explode on a warm day. Do not leave a loaded section over the noon hour, particularly on cool days, because when the dynamite becomes chilled it is less effective.

Safety in exploding is increased by using a No. 6 electric cap at least 300 feet of lead wire, and a blasting magneto. Work on the side from which the wind is blowing. Frequently, the lead wire and magneto for exploding the charge can be borrowed.

Keep the dynamite and caps stored in separate boxes and under lock and key. Do not connect wires to the magneto until time for the blast. One should not smoke while the explosives are handled nor while working close to them. Use a wooden wedge and a wooden mallet to open the boxes of dynamite. Any kind of metal may strike a spark. Remember that dynamite is made to explode. Be sure to follow all the safety precautions. One can not profit by his mistakes in using dynamite.

In many counties, experienced ditch blasters are available who can be hired to take the responsibility. Soil Conservation Service Technicians, County Agents, and Explosive Company Representatives can also give helpful information about ditch blasting. Most makers of explosives publish excellent hand books for use in ditching with dynamite.

PART V. CONSTRUCTING DIVERSION TERRACES

A diversion terrace is a combination channel and terrace, so located and constructed, that it collects and diverts excess water from the land above it. This same type of structure is used on long or steep slopes to reduce erosion. A diversion terrace has an important function in a surface drainage system by protecting low-lying crop or pasture fields from the on-flow of excess water originating on fields up the watershed. In effect, it is a dike that operates as a barrier to the direction of the flow of excess water.

Thus, diversion terraces function only where the land slopes. Frequently, there is enough slope and a large enough watershed to be the cause of a drainage problem even though it is not apparent to the unaided eye.

Water from land in the same field, another field, in the woods, pasture, or from a neighbor's farm may be slowly flowing onto a field.

Fig. 15—A diversion terrace which collects and diverts excess water from land above it.

The terrace shown in Figure 15 keeps the excess water where the operator is pointing from flowing onto the crop land to the right of the terrace.

This terrace was made with a plow and a two-plow tractor. The procedure was new to the farmer, but he had little difficulty in following the instructions of the Soil Conservation Service Technician, who was on hand when the ditch was made.

Note that the spoil bank has been used to increase the capacity of the structure. Thus, the terrace where the operator is standing serves a very useful purpose. This permits a shallower channel; one which can be crossed, if necessary, and which is not hazardous to grazing livestock.

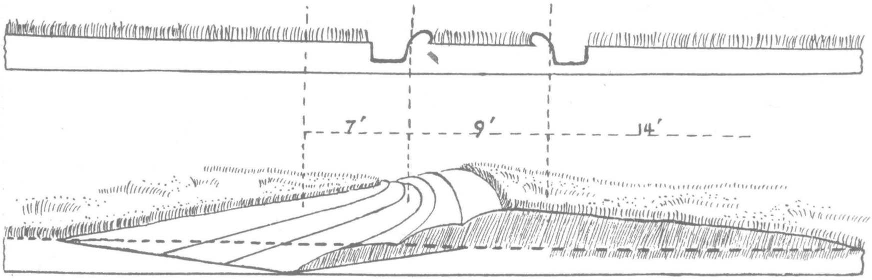

Fig. 16—A cross-section diagram showing the construction of a diversion terrace.

Steps in making a diversion terrace:

1. Carefully select the location so that effective diversion of water will result. In situations where the slope is unusually long, two or more terraces running crosswise of the slope will be useful. Frequently, it is possible to locate the terrace at the end of a cultivated field where it will divert water from the pasture, woods, or another field. Where this can be done it will cause the least inconvenience in farming operations.
2. Have an experienced engineer check the design of terraces which will receive water from large areas.
3. Stake out the course of the future channel to obtain a grade of not less than $\frac{2}{10}$ percent. It is desirable to have one's plans checked by a Soil Conservation Technician or County Agent, who will use an engineering level.
4. Choose the time to make the ditch. The soil must be in condition to be moved readily. On most soils this means just dry enough to work. Some sticky soils work better in the fall, provided they are not too dry and hard.
5. Select the implements to be used. Generally the moldboard breaking plow and a tractor that operates at modern-day speed is most suitable.
6. Mow and remove vegetation if it is excessive.
7. Thoroughly disc the area if it is in heavy sod before starting to plow.
8. Turn the first furrow down the slope with the plow running just above the line of stakes as illustrated in Figure 16.
9. Move down the slope 6 to 12 feet (commonly 9 feet as shown in the illustration) and on the return trip, plow a furrow parallel to the original one. This will leave a strip of ground between the orginal two furrows which will never be plowed. Actually the terrace ridge will be piled on this unplowed area; the channel will be adjacent to it on the upper side as shown in Figure 16.

   Plow five additional furrows around the unplowed strip (if a two-furrow plow is being used, this means two more rounds). Adjust the plow so that the sixth furrow on the upper side is very shallow, thereby, eliminating a sudden drop-off into the ditch.
10. Disc the plowed ground thoroughly if it is in heavy sod.
11. Continue plowing. Start by throwing the original furrow on the upper side one furrow-width nearer the center of the unplowed strip. Complete each round by plowing on the down side until twelve original furrows have been plowed below the strip. Thus, while the six furrows on the upper side of the strip are being plowed once and replowed once, twelve original furrows are plowed on the lower side of the strip.

12. Repeated replowing is continued until the plowed earth from the upper and lower sides have met and formed a well rounded terrace ridge. By this time the channel will also have the desired proportions and a depth of 18 inches below the terrace ridge (before settling). Where a 9-foot unplowed strip was left, this usually requires replowing the upper side eight times in addition to the initial plowing; on the lower side, the same number of furrows but only three and one-half repetitions in addition to the initial plowing. These calculations are based on a 14-inch bottom plow. Twenty-seven rounds are required with a two-bottom 14-inch plow; 54, with a one-bottom 14-inch plow.
13. Develop a sod in the channel and on the terrace ridge. This procedure is discussed in Part VI, Maintaining Ditches and Grassed Waterways.
14. Check the adequacy of its outlet ditch or waterway.

PART VI. MAINTAINING DITCHES AND WATERWAYS INCLUDING THE USE OF SOD

Ditches should be cleaned and re-opened as required to permit them fully to serve their purpose.

Willows, shrubs, trees, and large weeds tend to clog and cause silting. They should, therefore, be kept under control.

Livestock should be kept off ditches and grassed waterways at the time the frost goes out of the ground and during periods of heavy rains. Pasturing benefits the sod if properly controlled.

Crossing ditches with implements should be avoided when the ground is soft lest wheel tracks become the location of new and unwanted channels.

Developing Sod on Waterways.—Generally, collection ditches, outlet ditches, and diversion terraces should be in permanent sod. Sod is needed on waterways that carry the run-off from collection ditches, and diversion terraces unless they discharge directly into an outlet ditch or established stream. Furthermore, it is often desirable to establish sod on the headland (turning strip).

Sod of heavy turf has several important advantages:

1. It protects the soil from washing and forming gullies.
2. It controls sloughing of ditch banks.
3. It discourages or retards the growth of weeds and willows.
4. It may provide pasture or hay which can be utilized.

Careful attention is necessary in establishing a permanent sod because there are numerous problems to overcome. Generally, there is very little organic matter in the surface soil of the waterway because the top soil has

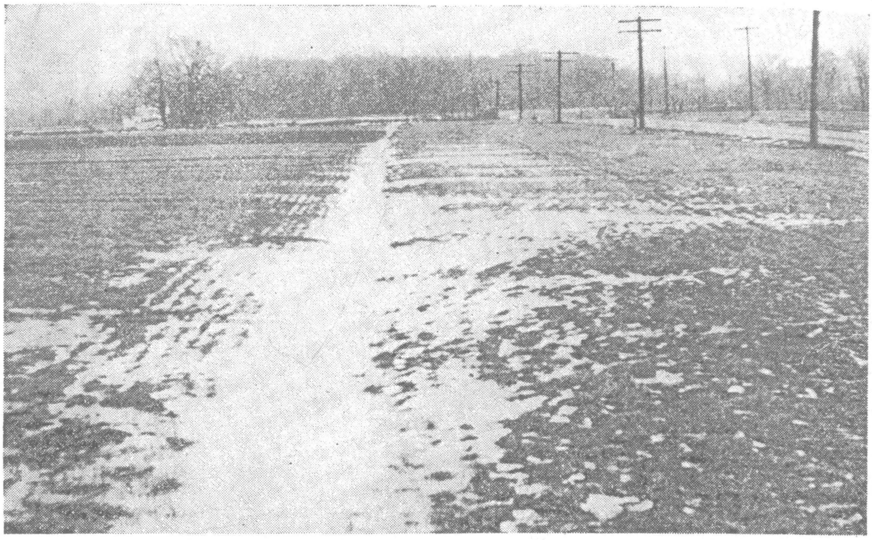

Fig. 17—Illustration of a waterway which should be in permanent sod. This is a collection-type ditch. Another is illustrated in Figure 2.

been removed in construction or in erosion, and secondly, the seeds or young plants may be washed away before they are established.

The following steps will be helpful in developing a permanent sod:

1. Recognize the hazards and provide the extra care that must be given.
2. Apply lime as needed to neutralize the acidity.
3. Apply a complete fertilizer such as 3-12-12 at the rate of 500 to 600 pounds per acre.
4. Plow under and disc into the soil a heavy application of manure.
5. Work down sharp sides.
6. Seed a suitable hay or pasture mixture. The following mixture is good: 6 pounds Kentucky bluegrass, 4 pounds timothy, 3 pounds alsike clover, 7 pounds alfalfa, and 1 pound Ladino clover. This is sufficient seed for a waterway equal to 1 acre.
7. Include a small grain for it will aid the sod plants to get established.
8. Apply a light top dressing of manure after the seeding is made.
9. Permit controlled grazing in the pasture field.
10. Mow twice each year.
11. Control weeds and woody plants.
12. Apply fertilizer to the permanent sod every other year and manure and lime every four years.